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THE TEACHING AND APPLICATION OF MANUFACTURING TECHNIQUES AND PROCEDURES

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THE TEACHING AND APPLICATION OF MANUFACTURING TECHNIQUES AND PROCEDURES

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1. The technology of production is perhaps best defined as the technology of converting ideas into designs, and designs into realities, in a manner which ensures that the product is both technically efficient and economically competitive. Success depends finally on the efficient combination of theoretical and practical necessities and possibilities. The teaching and application of manufacturing techniques and procedures must, therefore, be theoretically sound without being divorced from considerations of practical aspects.

2. The knowledge and ingenuity of scientists and engineers together with the experience and skill of technicians and craftsmen have helped in developing the manufacturing techniques and procedures at present used in the industries of the world. Their successful application demands not only sound planning and provision of the necessary equipment, but also the ability to operate and maintain such equipment in a state of optimum efficiency. The men who are to be entrusted with carrying out these tasks must, therefore, be taught the fundamentals of the processes, procedures and skills of their application, and the principles and techniques of running and servicing the equipment.

3. The manufacturing processes which have to be considered in this connection must be viewed less from the points of view of their immediate economic efficiency than from those of the operating conditions and the soundness of the product. Moreover, if a teacher is expected to produce, in a relatively short time, results which are to give rise to efficient industrial development, it will be unwise for him to try and cover every possible aspect, process and procedure available anywhere in the world; restraint may, in this case, be preferable to excessive ambition. As it would further be imprudent to attempt the introduction of sophisticated techniques before the basic techniques are thoroughly mastered, priority should be given to the study and application of those processes and procedures which are particularly suited to the prevailing climatic and living conditions, which are essential, easily taught and quickly applicable, and which at the same time cover the most urgent specific industrial needs. Special consideration should also be given to the fact that skilled and experienced operators are unlikely to be

abundantly available during the initial period of industrial development. Moreover, the teaching of manufacturing techniques must not be directed exclusively towards the creation of new products. It must be equally concerned with the maintenance and repair of products imported from the industries of the world. A certain degree of industrial independence should, however, be the immediate aim, and a trend of development from the maintenance of imported products towards the manufacture of new ones should be borne in mind.

4. The following considerations must govern the planning of the teaching programme.

(a) The technical and economic efficiency of manufacturing techniques and procedures depend upon:-

(i) The selection and correct application of the process which is most suitable for a particular case;

(ii) The knowledge of the parameters which affect the efficiency of the operations, as well as the cost and the quality of the product;

(iii) The skill of the operator who is carrying out the work.

(b) The teaching and training must, therefore, be approached on three levels:-

(i) The education of qualified engineers who are to study the fundamentals and are able to carry out research into specific problems;

(ii) The teaching of technicians who are to plan and supervise the operations in the workshop;

(iii) The training of craftsmen.

5. At what might be called the academic level, the teaching should aim at bringing out those parameters which affect the production efficiency. The subjects to be covered include, therefore, the mechanism of the processes, the types and capacities of plant and equipment and the cost of installation, handling and maintenance. Engineering problems cannot be separated into watertight compartments and the foundation for success in applying different manufacturing methods is laid at the design stage of the products, and during the development of suitable techniques for their manufacture and quality control. The academic teaching must, therefore, include the fundamentals of engineering design, metallurgy and metrology and it must be backed by laboratory testing and research.

6. Although it is possible to send students from the less developed areas to established places of study in the industrially more developed countries, suitable teaching and research facilities must be provided at an early date within the countries in which such students are expected to carry out their work. The initial handicap of lacking tradition may be overcome, during a "running-in" period, by the appointment of experienced teachers who have at their disposal good laboratory facilities.

7. The laboratories need not be filled with a great variety of plant and equipment. It is more important that the essential points of some typical processes under discussion are brought out. If, for example, a reasonably well equipped workshop is available for manufacturing research equipment (see e.g. paragraph 11 and 12), the following may form the nucleus for a laboratory dealing with metal cutting on the "academic undergraduate and post-graduate level":

(a) A rigid centre lathe (at least 25 HP with an infinitely variable speed range of 20-2000 r.p.m.);

(b) Rigid milling machines, if possible one horizontal and one vertical machine, (at least 15 HP with a speed range of 15-1500 r.p.m.);

(c) A tool and cutter grinding machine for the above;

(d) A cylindrical grinding machine;

(e) A small radial drilling machine;

(f) Equipment for cutting force measurement (see paragraph 12);

(g) Vibration excitation and measuring equipment;

(h) Precision metrology equipment for dimensional, shape and alignment measurement.

8. Apart from those who are to introduce a process into industry, ensure its correct application, and keep its use and development in line with developments elsewhere, a large number of men and women must be taught how to plan and supervise the work whilst others must be trained in the operation of theequipment. Perhaps the easiest of these jobs is the training of the operators. This can be done by sending to various centres a certain number of trainees who after their return can help in training their fellow workers. A more difficult task on the other hand is that of teaching technicians who must not only learn the bare facts but must also understand the basic principles. Only a thorough explanation of the principles will lead to the full appreciation of the opportunities offered and the limitations encountered, thus enabling the students to see how best use is made of different processes, either singly or in combination. Moreover, the discussion of the techniques must be closely linked with an appreciation of the need for ensuring the required quality of the finished article.

9. Great care must be taken not to overload the practical man with theoretical knowledge nor to expect the technician to become an accomplished craftsman. For example, it would be futile to teach a craftsman welder the various features of automatic welding equipment, in the same way as it would be inefficient if a welding engineer were trained in the most effective handling of manual arc welding sets at the expense of not being introduced to the possibilities and limitations of automatic equipment. It is also a mistake to mix teaching workshops and laboratories. The future engineers and technicians have to study the various parameters for obtaining satisfactory results under varying conditions with different processes and equipment, applied to different materials and for a variety of purposes. Demonstrations combined with explanations of the principal phenomena must be given in a laboratory to the technicians in order to acquaint them with the processes,

the problems of equipment maintenance and the principles of supervising operatives and inspecting finished products. Some explanations of such phenomena may, of course, be given to technicians by means of practical exercises in the laboratory, and valuable use can also be made of visual aids, especially the many films which are now becoming available and which can often bring out the essential points more clearly than demonstrations. The future craftsman, on the other hand, who has to be trained in handling the types of equipment which he will be likely to use, must be enabled to practice extensively the actual operations in a suitable workshop.

10. One of the most important tools in technical education is a generous supply of inexpensive technical books. Students at education institutes of University standard can be assumed to possess a working knowledge of English or another major language, and will thus be able to peruse the existing literature. Technicians and craftsmen, on the other hand, cannot be expected to be such linguists and for them books in their own language, either original or translations, must be provided. The contents of these books must, of course, be adapted to the state of the economic development of the respective countries, and any translations from major languages must, therefore, be thoroughly revised.

11. One of the difficulties often encountered in laboratory work is the fact that skilled demonstrators are required to handle the equipment because the students lack the necessary skill. On the other hand, a student may greatly benefit from some more direct practical contact with various processes. An example of how this problem can be solved may be shown for the case of welding. Here students have to study the parameters involved in obtaining sound welded connections under varying conditions, with different procedures and applied to a number of materials. The information which has to be conveyed includes the most important technological aspects, questions affecting the metallurgical and mechanical properties of the material and joints and problems of producing designs which take into account the possibilities and the limitations created by the application of welding to production and repair work. The simple arc welding device (Fig. I) which can easily be built, will enable the student to study arc characteristics, observe the phenomenon of arc blow, etc., at the same time eliminating the influence of his lack of skill when holding the arc. A welding electrode (a) is held in a standard electrode holder (b) by means of a clamping spring (c) which substitutes the hand grip of the operator. The electrode holder is held in carrier (d) which can swivel round fulcrum pin (e). A flicker movement of ratchet lever (f) pushes electrode (a) downwards to touch plate (g) on slide (h). After the edge of (f) has passed that of tail (i) of carrier (d) during the continuation of the downward movement of (f), carrier (d) is rapidly taken back under the pressure of spring (c) and an arc is drawn between plate (g) and electrode (a). Slide (h) can be moved along under electrode (a) either by means of hand lever (k) or by a power drive at a predetermined speed. If plate (g) is fastened horizontally to slide (h) the arc length will increase in accordance with the melting-off rate of the electrode; if plate (g) is fastened in an inclined position (g_1) the arc length can be kept constant by adjusting the travelling speed in proportion to the melting-off rate of the electrode. In both cases the movement of slide (h) can be carried out steadily by the student who observes the arc through welding screen (l). The welder's skill of

maintaining a steady arc length is replaced by the slide arrangement and the student finds but little difficulty in carrying out the experiment during which, for example, current and voltage measurements can also be taken under various conditions. The relation between arc voltage (increasing with arc length) and arc current for various types of supply equipment can then be determined, the phenomenon of arc blow and its prevention can be demonstrated under different conditions, and the student can carry out the complete experiment without being an experienced welder.

12. In the study of machining operations it is again unnecessary to use expensive equipment. Relatively simple dynamometers 1), 2), have proved most valuable for demonstrating and measuring the main cutting force components. For example, cantilever dynamometers as shown in Fig. II 2), can be produced in the workshop of a technical college, and quickly calibrated and easily used for a variety of experiments in the laboratory. The parameters affecting the performance of cutting tools can be demonstrated and little skill is required on the part of the student in handling these instruments.

13. In paragraph 3 the need for carefully selecting appropriate manufacturing processes was already mentioned. Whilst it would go beyond the scope of this paper to submit a complete list of procedures and techniques which are considered suitable for the purpose and which can be relatively easily taught and introduced into industry, some considerations affecting such a selection may not be out of place. At the 1962 Machine Tool Colloquium at Aachen Professor Opitz 3) gave a comprehensive survey covering the present position and importance of manufacturing processes. These can be grouped as follows:-

(a) Processes which produce primary components from the raw material (casting, moulding and forming).

(b) Fabricating processes for the production of components from a number of separate detail parts.

(c) Machining processes.

14. In general industrial practice the reasons for deciding on the selection of one of these processes are:-

(a) Technological, determined by:-

(i) Type and size of the product;

(ii) Material properties;

(iii) Quality required;

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1) Robinson, F. and Gregory, R. W., A Cutting Torque Dynamometer and Related Experiments, Bulletin of Mechanical Engineering Education, No. 4, July, 1953.

2) Heginbotham, W. B., A Simple Two Component Cantilever Lathe Tool Dynamometer, Bulletin of Mechanical Engineering Education, No. 7, January, 1955.

3) Opitz, H., Stand und Bedeutung der Technologie der Fertigungsverfahren, 11th Werkzeugmaschinenkolloquium, Aachen, 1962. Industrie-Anzeiger, 7 Sept. 1962.

(b) Economic:-

(i) Required quantities;

(ii) Cost of material;

(iii) Cost of equipment;

(iv) Cost of operation.

15. Whilst the items under 14. are, in fact, generally applicable, in the case under discussion the feasibility of employing certain processes, types of equipment and operations is further affected by:-

(a) The available facilities, viz:

(i) Site;

(ii) Power supply;

(iii) Transport and handling.

(b) The possibility of providing the manpower for planning the operations, for running and operating the equipment and for carrying out the necessary quality control:-

(i) Qualified engineers;

(ii) Technicians;

(iii) Skilled craftsmen;

(iv) Unskilled labour.

16. Among the items mentioned in paragraph 15. those under (b) are perhaps the more important ones for the case under discussion. A shortage of skilled machine operators may make the use of automatic equipment advisable. This requires, however, good planners, skilled machine setters, and last but by no means least, a very good maintenance staff. In this connection it may make matters easier, if some maintenance staff from the manufacturer of imported automatic equipment can be employed rather than relying on the skill of newly trained machine operators. It should also be remembered, moreover, that the raw material must be very thoroughly prepared when automatic processes are employed. An automatic arc welding machine, for example, does not produce a sound joint unless the plate edges are more accurately prepared than would be necessary for manual welding.

17. The need for skill in operating machine tools can be reduced by the use of jigs and fixtures, and if there is a shortage of skilled tool makers the use of universal fixture systems 4) will assist in producing the jigs and tools which are essential for interchangeable manufacture. The manufacture of interchangeable components in turn helps to reduce the load on the skilled fitting staff. If such components can be produced in accordance with generally accepted standards, they can be used, if necessary in conjunction with imported components, thus easing difficulties which may be caused, for example, by the lack of certain equipment. Interchangeable manufacture is, however, only possible if the quality control is based on sound metrological

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4) Barash, M. M., Heginbotham, W. B., and Oxley, P. B. L., Jigs and Fixtures from Standard Sets of Parts. Engineering, Vol. 185, 27 June, 1958.

principles, i.e. if suitable gauges are available and can be checked against reliable standards. This requires first class metrology equipment and, if possible, a standards room.

18. It would go beyond the scope of this paper to mention the many new processes which have recently been developed with a view to increasing productivity in the fully industrialised countries and which could help in establishing efficient industries in less developed areas. Among such processes are:-

(a) Precision casting: Production of moulds for castings by means of the "Plycast" process 5).

(b) Welding 6)

(i) CO_2 welding;

(ii) Electro-slag welding of heavy sections.

(c) Preparation of forging dies

Spark erosion machining.

(d) Forming processes 7)

(i) Cold extrusion;

(ii) Explosive forming;

(iii) Dynapack-forming,

and many others.

19. The essential condition for successfully starting industrial organisations, for effectively providing the necessary plant and equipment, and for applying the various manufacturing methods and techniques which make efficient production possible, is the availability of staff capable of carrying out the design, planning, supervision, execution and inspection of the work required. It may be argued that it is possible to import plant and machinery, and to invite from abroad qualified engineers and skilled craftsmen to carry out the work. However, the whole life of a country, and not only one particular factory, is involved in the processes of production which affect building, power supply, transport, communication, etc. to such an extent that the mere transfer of the plant and staff for one factory would be almost bound to fail. The most important task is, therefore, the creation of facilities for teaching and training the population in such a manner as to enable everybody to do his share in driving the country's economy along the road from hard work to prosperity. Rather than trying merely to supply the the equipment or even the actual products, it is the duty of the more developed and industrialised countries to assist to the utmost the people in the less developed areas in reaching their goal; in other words, to help them to help themselves.

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5) Heimann, K. W., Neue Verfahren auf dem Gebiete der Giesstechnik, 11th Werkzeugmaschinenkolloquium, Aachen 1962, Industrie-Anzeiger, 7th Sept. 1962.

6) Numerous publications on these processes have appeared in the Welding Journal, The British Welding Journal, Schweissen und Schneiden, etc.

7) See footnote 3).

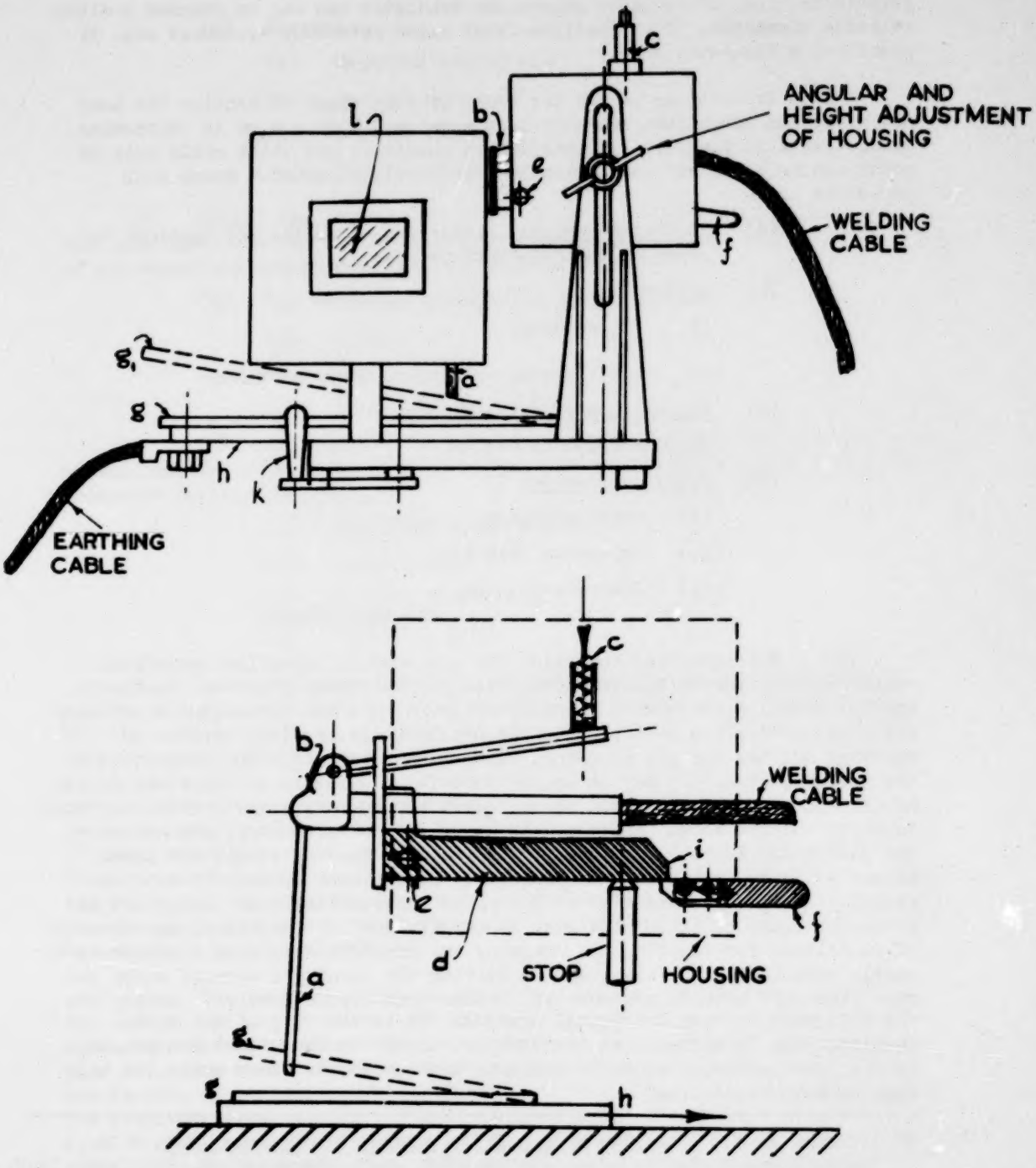
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Figure I.

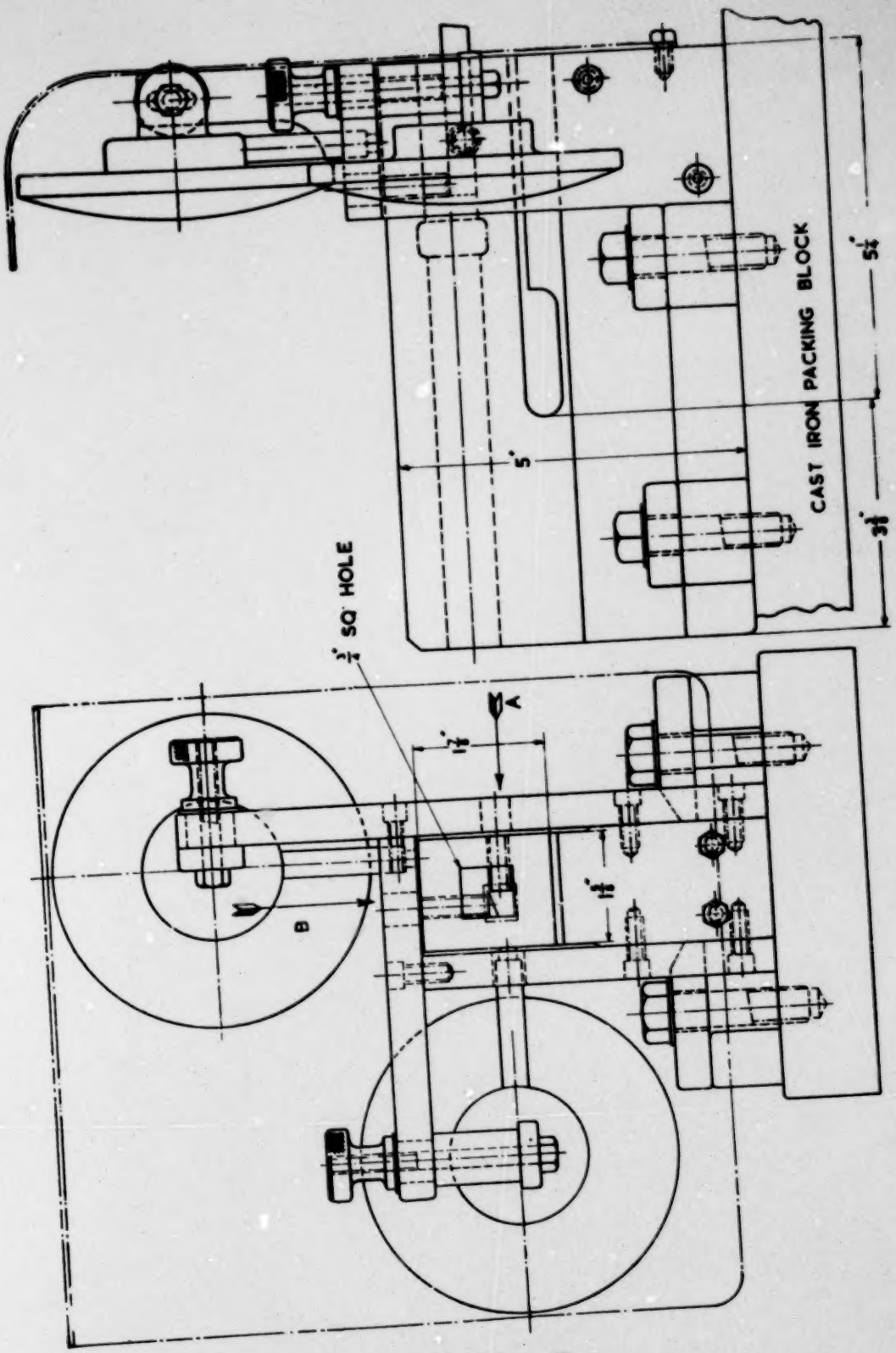

Figure II.

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